(51) International Patent Classification.4 :		(11) International Publication Number: **WO 89/ 00757**
H01B 7/02, 3/10, 3/42 H01B 3/44	A1	(43) International Publication Date: 26 January 1989 (26.01.89)

(21) International Application Number: PCT/GB88/00546

(22) International Filing Date: 8 July 1988 (08.07.88)

(31) Priority Application Number: 8716305

(32) Priority Date: 10 July 1987 (10.07.87)

(33) Priority Country: GB

(71) Applicant *(for all designated States except US)*: RAY-CHEM LIMITED [GB/GB]; Rolls House, 7 Rolls Buildings, Fetter Lane, London EC4 1NH (GB).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)* : PENNECK, Richard, John [GB/GB]; Treeve, Westway, Lechlade, Gloucestershire GL7 3AU (GB).

(74) Agents: DLUGOSZ, A., C.; Raychem Limited, Faraday Road, Dorcan, Swindon, Wiltshire SN3 5HH (GB) et al.

(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

Published
With international search report.

(54) Title: ELECTRICAL WIRE

(57) Abstract

An electrical wire comprises an elongate electrical conductor, an inorganic arc-control layer surrounding the conductor, an insulating layer which surrounds the arc-control layer and comprises an aromatic polymer, and a secondary tracking control layer surrounding the insulating layer, the secondary tracking control layer having a comparative tracking index of at least 300V. The wire exhibits good electrical and mechanical properties characteristic of highly aromatic polymers together with good resistance to dry arcing and wet tracking.

ELECTRICAL WIRE

This invention relates to electrical wires, and especially to wires that employ electrical insulation based on aromatic polymers.

Electrical wire and cable that use aromatic polymer insulation have been used for many years in numerous applications. For example wires that employ polyimide wraps or tapes usually bonded with fluoro-polymer adhesive layers have been used extensively as aircraft wire, for both civil and military applications. Other examples of aromatic insulation that have been used for equipment wire or "hook-up" wire, air frame wire and in wire harnesses include aromatic polyether ketones, polyether ether ketones, modified polyphenylene oxide, and polyimide amides. Highly aromatic polymers have been used successfully in many applications because they have a range of desirable properties especially high strength and toughness, abrasion resistance, temperature resistance, dielectric strength and are often inherently highly flame-retarded.

The combination of these properties has enabled wire and cable fabricated from these polymers to be

used in small lightweight constructions. Such constructions have been used increasingly in both military and civil applications due to the high density and complexity of modern electrical systems.

However, these highly aromatic polymers suffer from a major problem: they are particularly susceptible to tracking. Tracking is a phenomenon associated with the formation of permanent and progressive conducting paths on the surface of the material by the combined effects of an electrical field and external surface pollution. Once commenced, the carbonaceous conducting deposits often extend quickly in dendritic fashion to give a characteristic "tree" pattern until failure occurs across the surface. Electrical tracking can occur when a damaged energised bundle of wires become wet e.g. from electrolytes or condensation. This tracking may lead to flashover and arcing that causes additional wires in the bundle to become damaged. A catastrophic cascade failure can result from a fault to a single wire if adjacent wires that are at a different electrical potential are also susceptible to tracking or if the bundle is in contact with a grounded structure. Tracking can occur at low voltages e.g. 100V a.c. or less but becomes less likely as the voltage is reduced.

A related phenomenon, to which these polymers are also highly susceptible, is that of breakdown due to arcing. In this case a potential difference between two conductors, or between a conductor in which the insulation has been mechanically damaged, and ground, can result in the formation of an arc between the con-

ductors or between the conductor and ground. The high
temperature of the arc causes the polymer to degrade
extremely rapidly and form an electrically conductive
carbonaceous deposit which can extend rapidly, as with
wet tracking, and lead to catastrophic failure in which
many or all of the wires in a bundle are destroyed.
Arcing can occur at very low voltages, for example 24V
d.c. or lower, and since, unlike tracking, no electro-
lyte or moisture is involved, it is a particularly
hazardous phenomenon. Arcs may also be struck by
drawing apart two conductors between which a current is
passing as described for example by J.M. Somerville
"The Electric Arc", Methuen 1959.

Another phenomenon that can be associated with
tracking and arcing is erosion. In this case insu-
lating material is removed by a vaporization process
originated by an electrical discharge without the for-
mation of electrically conductive deposits so that
failure of the insulation will not occur until complete
puncture of the insulation occurs.

According to the present invention, there is pro-
vided an electrical wire which comprises an elongate
electrical conductor, an inorganic arc-control layer
surrounding the conductor, an insulating layer which
surrounds the arc-control layer and comprises an aroma-
tic polymer and a secondary tracking control layer
surrounding the insulating layer, the secondary
tracking control layer having a comparative tracking
index of at least 300V. The "comparative tracking
index" (C.T.I.) of a polymer is defined below.

- 4 -

By forming a wire in accordance with this inven-
tion it is possible to utilise the very good thermal,
mechanical and electrical properties of aromatic poly-
mers without the wire exhibiting a high propensity to
track which is associated with highly aromatic poly-
mers.

The aromatic polymer will normally have a car-
bonaceous char residue of at least 25%, preferably at
least 30%, some polymers having a char residue of at
least 40% and even at least 50%. This does not mean to
say that a high char value is desired for its own sake,
but simply that good mechanical and physical properties
of these aromatic polymers including temperature stabi-
lity and fire retardancy, are usually associated with
high char residues.

The char residue of the polymer components in the
electrical wire according to the invention can be
measured by the method known as thermogravimetric ana-
lysis, or TGA, in which a sample of the polymer is
heated in nitrogen or other inert atmosphere at a
defined rate, e.g. 10°C per minute to a defined tem-
perature and the residual weight, which is composed of
char, is recorded. The char residue is simply the
quantity of this residual char expressed as a percen-
tage of the initial polymer after having taken into
account any non polymeric volatile or non-volatile com-
ponents. The char residue values quoted herein are
defined as having been measured at 850°C and at a
heating rate of 10°C per minute.

The preferred aromatic polymers which are used in
this invention are well known to those skilled in the

- 5 -

art, and reference may be made for example to U.S.
Patents Nos. 3,025,605, 3,306,874, 3,257,357,
3,354,129, 3,441,538, 3,442,538, 3,446,654, 3,658,938,
3,677,921, 3,838,097, 3,847,867, 3,953,400, 3,956,240,
4,107,147, 4,108,837, 4,111,908, 4,175,175, 4,293,670,
4,320,224, and 3,446,654, British Patents Nos.
971,227, 1,369,210 and 1,599,106 and European Patent
Applications Nos. 170,065, 124,276 and 178,185. Such
polymers include polyketones, polyether ketones,
polyether ether ketones, polyether sulphones, polyether
ketone/sulphone copolymers, polyether imides and
polyphenylene oxides. Blends of different polymers can
be used. The polymers may be wholly aromatic or they
may include one or more aliphatic moieties which may
comprise pendant alkyl groups or may comprise alkylene
groups in the polymer backbone. Preferably the or each
aliphatic moiety has not more than 4, and more pre-
ferably not more than 3 carbon atoms. In the case of
pendant alkyl groups, each group is most preferably a
methyl group, while in the case of alkylene groups each
group preferably has not more than 3 carbon atoms, and
especially only one carbon atom, in the chain backbone,
for example a methylene or isopropylidine group.

Preferred aromatic polymers are polymers with a
melting or softening point of at least 250°C, par-
ticularly at least 300°C and which may be crystalline
or amorphous. Softening points of amorphous polymers
may conveniently be measured by thermomechanical analy-
sis (TMA), in which case the softening point refers to
the temperature at which the probe has reached 60%
penetration. In one class of such polymers the polymer
comprises, and preferably consists essentially of,
units of the formula
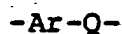
- 6 -

-Ar-Q-

the units being the same or different,

wherein Ar represents an unsubstituted or substituted
divalent aromatic radical and Q represents -O-, -S-,
$-SO_2-$, -CO-, -NH-CO- or -COO-, or Ar represents a poly-
valent radical and Q represents

$$-N\underset{CO-}{\overset{CO-}{\diagdown}}$$
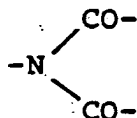
each bond of the Q radical preferably being bonded
directly to an aromatic carbon atom.

One preferred class of polymer comprises the
polyphenylene oxides of the repeating unit
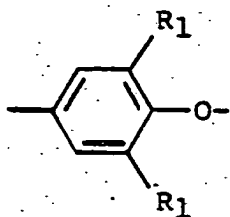
in which the groups R_1, which may be the same or dif-
ferent, each represents a hydrogen or halogen atom or a
hydrocarbon atom having no tertiary alpha carbon atom.

In another class of aromatic polymers the aromatic
polymer is a crystalline polyarylene ether comprising
recurring units of the formula
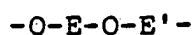
-O-E-O-E'-

where E is the residue of a dihydric phenol and E' is
the residue of an aromatic compound having an electron
withdrawing group in at least one of the positions
ortho and para to the valence bonds, the E and E' radi-
cals being linked to the -O- radicals through aromatic
carbon atoms. In one preferred sub-class, E is a radi-
cal of the formula
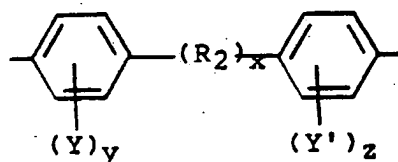
wherein R_2 is a divalent radical; x is 0 or 1; Y is a
radical selected from halogen atoms, alkyl radicals
containing 1 to 4 carbon atoms and alkoxy radicals con-
taining 1 to 4 carbon atoms; y is 0, 1, 2, 3 or 4; Y'
is a radical selected from halogen atoms, alkyl radi-
cals containing 1 to 4 carbon atoms and alkoxy radicals
containing 1 to 4 carbon atoms; z is 0, 1, 2, 3 or 4,
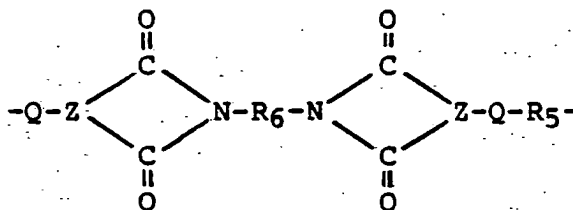and E' is a radical of the formula
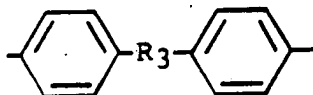
wherein R_3 is a sulphone, carbonyl, vinyl, sulphoxide,
azo, saturated fluorocarbon, organic phosphine oxide or
ethylidene radical. In this class preferred poly-
sulphones are those in which y and z are 0, x is 1, R_3
is a sulphone radical and R_2 is a radical of the for-
mula

$$\begin{array}{c} R_4 \\ | \\ -C- \\ | \\ R_4 \end{array}$$
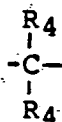
wherein each of R_4 is independently selected from the group consisting of hydrogen; alkyl radicals containing 1 to 4 carbon atoms; halogen-substituted alkyl radical containing 1 to 4 carbon atoms; aryl, alkaryl and aralkyl radicals containing 6 to 10 carbon atoms; and halogen-substituted aryl alkaryl and aralkyl radicals containing 6 to 10 carbon atoms.

In another class of aromatic polymers, the polymer is a polyether imide or polysulphone imide which comprises recurring units of the formula

$$-Q-Z\underset{\underset{O}{\overset{O}{\underset{\parallel}{C}}}}{\overset{\overset{O}{\underset{\parallel}{C}}}{\diagdown}}N-R_6-N\underset{\underset{O}{\overset{O}{\underset{\parallel}{C}}}}{\overset{\overset{O}{\underset{\parallel}{C}}}{\diagup}}Z-Q-R_5-$$

where Q is -O- or $-SO_2-$, Z is a trivalent aromatic radical, R_5 is a divalent aromatic radical and R_6 is a divalent organic radical. Preferably the aromatic polymer has the general repeat unit
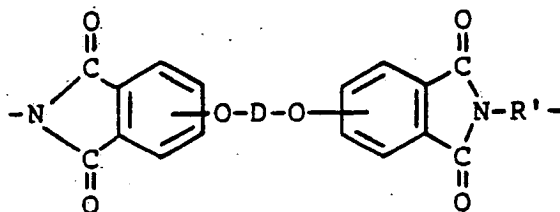
in which D represents a group of the formula:
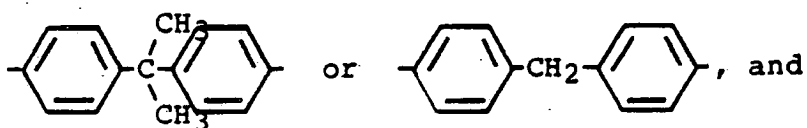
R' represents an arylene group.

Another class of polymers is the polyetherketones that have repeating groups comprising aromatic ether and aromatic ketone groups together with an imide, amide, ester, benzoxazole or benzothiazole group. Examples of such polymers are those having repeating units of the formula:
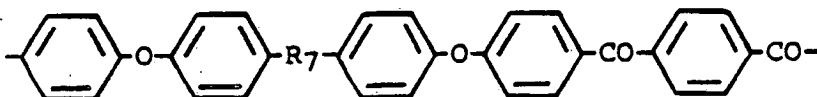
where R_7 represents an imide, amide or ester group.

Yet another class of aromatic polymer is the polyarylates. Polyarylates that may be used include those that are derived from dihydric phenols and at least one aromatic dicarboxylic acid. Examples of such polymers include those derived from a dihydric phenol of the general formula

- 10 -
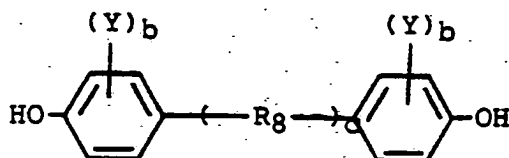
in which the groups Y, which may be the same or different, each represent a hydrogen atom, a C_1 to C_4 alkyl group, or a chlorine or bromine atom; b is 0 ir an integer from 1 to 4; R_8 represents a divalent saturated or unsaturated hydrocarbon group, e.g. an alkylene, alkylidine, cycloalkylene or cycloalkylidine group, an oxygen or sulphur atom or a carbonyl or sulphonyl group; and c is 0 or 1.

Preferred aromatic polymers consist essentially of repeating units having one of the following formulae
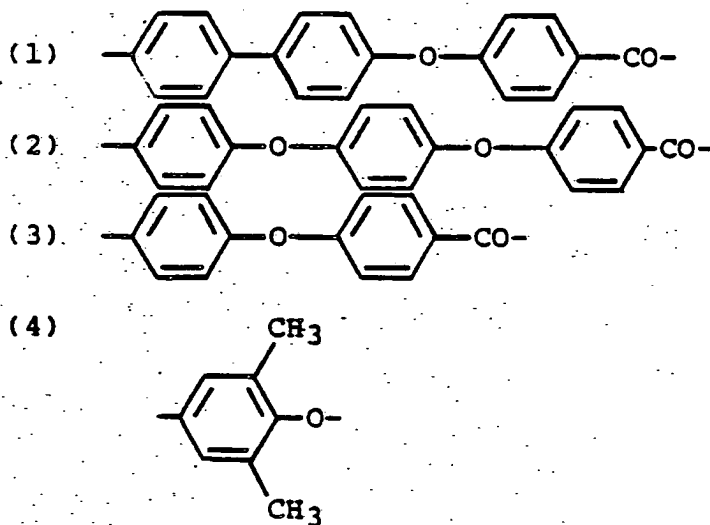
(5)
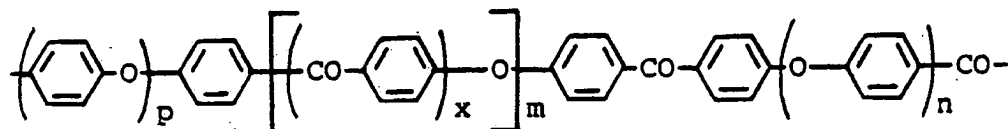
wherein each of x, m and n is 0 or 1, with n being 0 when x is 1, p is an integer from 1 to 4, with m being 1 and x being 0 when p is greater than 1, e.g.,

, or

,

(6)

(7)

(8)

- 12 -

or

(9.)
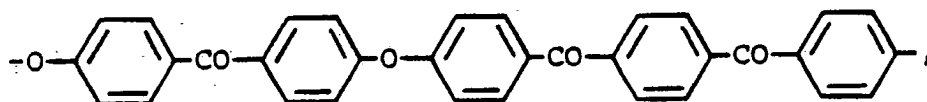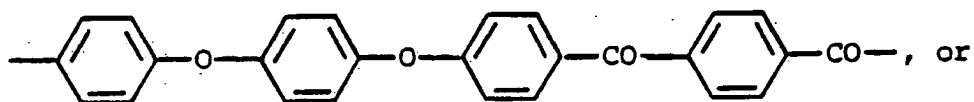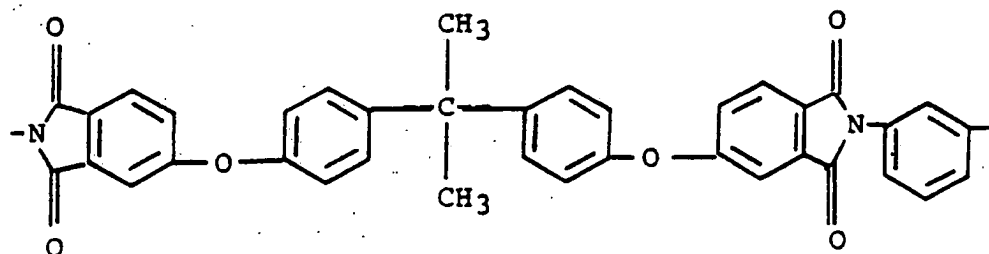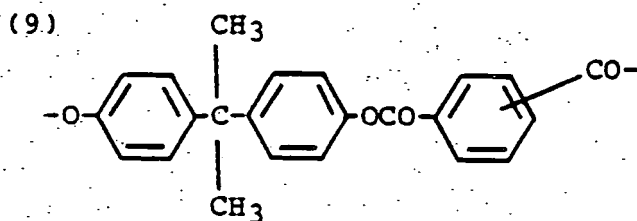
in which units derived wholly from isophthalic acid or
terephthalic acid or a mixture of both are present.

Other polymers having aromatic moieties e.g. poly
1,12-dodecamethylene pyromellitimide or
1,13-tridecamethylene pyromellitimide, as described in
U.S. patent No. 3,551,200, may be used.

Blends of any two or more of the above polymers
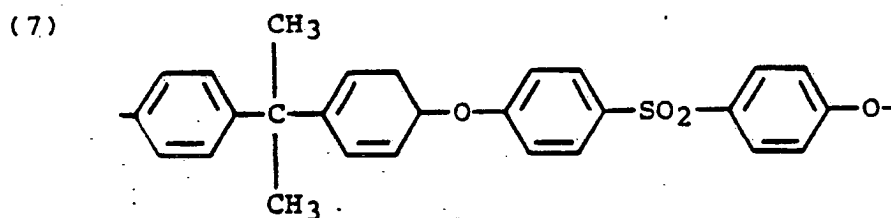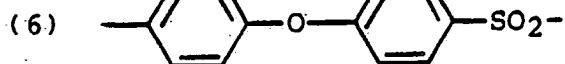may be employed as may copolymers based on any two or
more of these polymers.

The preferred aromatic polymers will usually have
a molar C:H ratio of at least 1.0, preferably at least
1.2, more preferably at least 1.3 and especially at
least 1.4. The toughest polymers such as the polyaryl
ether ketones, which are associated with high char
residues, will have C:H ratios greater than 1.5.

The insulating layer may, in some cases, have an
inner surface that has a C.T.I. of at least 250V.
Preferably the C.T.I. of the inner surface of the prin-
cipal insulating layer is at least 300V and most espe-
cially at least 500V. Such values for the C.T.I. will
normally be associated with carbonaceous char levels of

not more than 10% by weight preferably not more than 5% by weight more preferably not more than 2% and especially 0%. The C.T.I. of the inner surface of the insulating layer may be achieved in certain cases by selection of the appropriate aromatic polymer. Alternatively it may be appropriate to blend the aromatic polymer with an aliphatic polymer in order to reduce the char level or increase the C.T.I. of the layer. We have found that the incorporation of an aliphatic polymer in the aromatic polymer can lead to a disproportionate reduction in the char residue of the blend, as described in our co-pending British patent application entitled "Electrical Wire and Cable" filed on even date herewith (Agent's ref: RK336), the disclosure of which is incorporated herein by reference. The preferred aliphatic polymers that may be blended with the aromatic polymer are the same as those referred to below for use as the secondary tracking control layer.

Alternatively or in addition, the insulating layer may be in the form of two or more layers, the outermost layer comprising the aromatic polymer, either alone or as a blend with one or more other polymers, and the inner layer comprising a polymer having a low char residue, e.g. not more than 10% by weight. The inner layer may, and preferably does, comprise one or more of the aliphatic polymers mentioned below.

The total thickness of the insulating layer will usually be in the range of from 50 to 250 micrometres, and especially from 75 to 200 micrometres. When it is in the form of more than one layer, the inner layer will normally have a thickness of from 75 to 125 micro-

metres, and the outer layer will normally have a thickness of up to 150 micrometres, preferably up to 100 micrometres, and especially up to 75 micrometres.

The purpose of the arc-control layer is to control the growth of the arc roots which, according to the invention, is achieved by controlling the arc diameter through the provision of a refractory, preferably adherent, layer on the electrical conductor, which will aid quick conductor melting and severence before more extensive wire or bundle damage can occur. Thus, for example, a layer of alumina, silica, silicon nitride, aluminium nitride, magnesium oxide, and titanium dioxide may be applied by any appropriate means, for example a vapour deposition method. Examples of such methods includes sputtering, chemical vapour deposition, flame spraying, plasma ashing, reactive ion plating, electron beam evaporation or by other techniques. Examples of refractory coatings and methods of forming them on a conductor are described in our patent application No. GB-2,144,260A (US 818,854), the disclosure of which is incorporated herein by reference. Alternatively a weathered mica coating may be employed, for example as described in our copending European applications filed on even date herewith and claiming priority from British applications Nos. 8716303 and 8716309, the disclosures of which are also incorporated herein by reference.

The thickness of the arc-control layer will depend on, amongst other things, the material from which it is formed. In the case of refractory layers, the thickness will normally be in the range of from 0.1 to

10 micrometres preferably 5 to 10 micrometres, and the
layer will preferably adhere to the electrical conduc-
tor for example by provision of a metallic or refrac-
tory interlayer. For other materials, thicknesses up
to 100 micrometres may be used.

As stated above, the secondary tracking control
layer has a C.T.I. of at least 300V. Preferably it has
a C.T.I. of at least 400V, more preferably at least
500V and especially at least 600V. This normally will
mean that the material from which the secondary
tracking control layer is formed will have a car-
bonaceous char residue of not more than 10%, more pre-
ferably not more than 5%, most preferably not more than
2% and especially 0% by weight. The secondary tracking
control layer preferably comprises an aliphatic polymer
or blend of aliphatic polymers, although it is possible
for the aliphatic polymer to include one or more
aromatic moieties in addition to its aliphatic
moieties, and indeed a number of preferred polymers do
so. However the polymer should have sufficient alipha-
tic nature that its molar C:H ratio is not more than 1.
Examples of aliphatic polymers and polymers containing
aliphatic moieties (which will be referred to herein
simply as aliphatic polymers for the sake of brevity)
include olefin homopolymers and copolymers of olefins
with other olefins and with other monomers e.g. vinyl
esters, alkyl acrylates and alkyl alkacrylates, e.g.
low, medium and high density polyethylene, linear low
density polyethylene and ethylene alpha-olefin copoly-
mers, ethylene/propylene rubber, butyl rubber, ethylene
vinyl acetate, ethylene ethyl acrylate and ethylene
acrylic acid copolymers, and linear or radial styrene

diene di- or tri-block copolymers e.g. styrene/buta-
diene, styrene/isoprene copolymers, styrene/butadiene/-
styrene and styrene/isoprene/styrene, and hydrogenated
versions of these block copolymers especially styrene
ethylene/butylene/styrene block copolymers. A par-
ticularly preferred class of low charring polymers is
the polyamides. Preferred polyamides include the
nylons e.g. nylon 46, nylon 6, nylon 7, nylon 66, nylon
610, nylon 611, nylon 612, nylon 11, nylon 12, nylon
1212, and aliphatic/aromatic polyamides, polyamides
based on the condensation of terephthalic acid with
trimethylhexamethylene diamine (preferably containing a
mixture of 2,2,4- and 2,4,4-trimethylhexamethylene
diamine isomers), polyamides formed from the conden-
sation of one or more bisaminomethylnorbornane isomers
with one or more aliphatic, cycloaliphatic or aromatic
dicarboxylic acids e.g. terephthalic acid and
optionally including one or more amino acid or lactam
e.g. ε-caprolactam comonomers, polyamides based on
units derived from laurinlactam, isophthalic acid and
bis-(4-amino-3-methylcyclohexyl) methane, polyamides
based on the condensation of 2,2-bis-(p-aminocyclo-
hexyl) propane with adipic and azeleic acids, and
polyamides based on the condensation of trans cyclo-
hexane-1,4-dicarboxylic acid with the trimethylhexa-
methylene diamine isomers mentioned above. Other
aliphatic polymers that may be used include polyesters
e.g. polyalkylene terephthalate and especially poly-
tetramethylene terephthalate, and cycloaliphatic
diol/terephthalic acid copolymers e.g. copolymers of
terephthalate and isophthalate units with 1,4-cyclo-
hexanedimethyloxy units, polysulphides, polyethers e.g.
polybutylene ether copolymers, and especially polyether

- 17 -

esters such as those having polytetramethylene ether
and polytetramethylene terephthalate blocks; aliphatic
ionomers e.g. those based on metal salts of ethylene
(meth)acrylic acid copolymers or sulphonated olefins
such as sulphonated EPDM, and the like.   Preferred
aliphatic polymers include the polyamides mentioned
above, polyethylene, polybutylene terephthalate, iono-
mers based on metal salts of methacrylated polyethy-
lene, acrylic elastomers e.g. those based on methyl,
ethyl or n-butyl acrylate or alkoxy-substituted ethyl
or n-butyl acrylate polymers containing a cure site
monomer and optionally ethylene comonomer, and block
copolymers having long chain ester units of the general
formula:
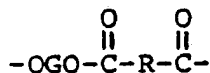
$$-OGO-\overset{\overset{\textstyle O}{\|}}{C}-R-\overset{\overset{\textstyle O}{\|}}{C}-$$

and short-chain ester units of the formula

$$-ODO-\overset{\overset{\textstyle O}{\|}}{C}-R-\overset{\overset{\textstyle O}{\|}}{C}-$$

in which G is a divalent radical remaining after
the removal of terminal hydroxyl groups from a
polyalkylene oxide) glycol, preferably a poly (C_2
to C_4 alkylene oxide) having a molecular weight of
about 600 to 6000; R is a divalent radical
remaining after removal of carboxyl groups from at
least one dicarboxylic acid having a molecular
weight of less than about 300; and D is a divalent
radical remaining after removal of hydroxyl groups
from at least one diol having a molecular weight
less than 250.

Preferred copolyesters are the polyether ester
polymers derived from terephthalic acid,
polytetramethylene ether glycol and 1,4-butane
diol. These are random block copolymers having
crystalline hard blocks with the repeating unit:

$$-(CH_2)_4-O-\overset{\overset{O}{\|}}{C}-\underset{}{\langle\bigcirc\rangle}-\overset{\overset{O}{\|}}{C}-$$
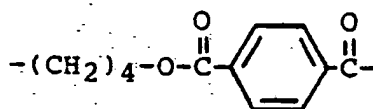
and amorphous, elastomeric polytetramethylene
ether terephthalate soft blocks of repeating unit

$$-\!\!\left[O(CH_2)_4\right]_n\!\!-O-\overset{\overset{O}{\|}}{C}-\underset{}{\langle\bigcirc\rangle}-\overset{\overset{O}{\|}}{C}-$$
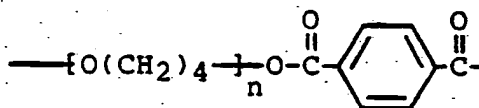
having a molecular weight of about 600 to 3000,
i.e. n = 6 to 40.

Other preferred aliphatic polymers include those
based on polyether and polyamide blocks, especially the
so called a "polyether-ester amide block copolymers" of
repeating unit:

$$-\overset{}{\underset{\overset{\|}{O}}{C}}-A-\overset{}{\underset{\overset{\|}{O}}{C}}-O-B-O-$$
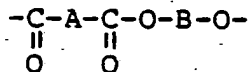
wherein A represents a polyamide sequence of average
molecular weight in the range of from 300 to 15,000,
preferably from 800 to 5000; and B represents a linear
or branched polyoxyalkylene sequence of average molecu-
lar weight in the range of from 200 to 6000, preferably
from 400 to 3000.

Preferably the polyamide sequence is formed from alpha,omega-aminocarboxylic acids, lactams or diamine/-dicarboxylic acid combinations that include C_4 to C_{14} alkylene carbon chains, and the polyoxyalkylene sequence is based on ethylene glycol, propylene glycol and/or tetramethylene glycol, and the polyoxyalkylene sequence constitutes from 5 to 85%, especially from 10 to 50% of the total block copolymer by weight. These polymers and their preparation are described in UK Patent Specifications Nos. 1,473,972, 1,532,930, 1,555,644, 2,005,283A and 2,011,450A.

The aliphatic polymer preferably has a C:H ratio of not more than 0.9, more preferably not more than 0.75, most preferably not more than 0.65 and especially not more than 0.55.

The aliphatic polymer may be unsubstituted or substituted. One class of aliphatic polymer that is particularly useful is the fluorinated polymers, preferably those containing at least 10%, more preferably at least 25% fluorine by weight. The fluorinated polymer may be a single fluorine containing polymer or a mixture of polymers one or more of which contains fluorine. The fluorinated polymers are usually homo-or copolymers of one or more fluorinated, often per-fluorinated, olefinically unsaturated monomers or copolymers of such a comonomer with a non-fluorinated olefin. The fluorinated polymer preferably has a melting point of at least 150°C, often at least 250°C and often up to 350°C, and a viscosity (before any crosslinking) of less than 10^4 Pa.s at a temperature of not more than 60°C above its melting point. Preferred

fluorinated polymers are homo- or copolymers of tetra-
fluoroethylene, vinylidine fluoride or hexafluoropropy-
lene, and especially ethylene/tetrafluoroethylene
copolymers e.g. containing 35 to 60% ethylene, 35 to
60% tetrafluoroethylene by mole and up to 10% by mole
of other comonomers, polyvinylidine fluoride, copoly-
mers of vinylidine fluoride with hexafluoropropylene,
tetrafluoroethylene and/or hexafluoroisobutylene, poly-
hexafluoropropylene, and copolymers of hexafluoropropy-
lene and tetrafluoroethylene. Alternatively C_1-C_4
perfluoroalkoxy substituted perfluoroethylene homo-
polymers and copolymers with the above fluorinated
polymers may be used.

The secondary tracking control layer may have a
thickness of up to 100 micrometres, e.g. from 50 to 100
micrometres in the case of a polymeric layer. Thinner
secondary tracking control layers may be provided by
other means.

The polymeric insulation of the wire is preferably
cross-linked. In general, however, the aromatic poly-
mers will exhibit a lower degree of crosslinking than
the aliphatic polymers, and in many cases the aliphatic
polymers may be highly crosslinked while the aromatic
polymers remain substantially uncrosslinked.

The polymeric composition may be cross-linked, for
example, by exposure to high energy radiation.

Radiation cross-linking may be effected by expo-
sure to high energy irradiation such as an electron
beam or gamma-rays. Radiation dosages in the range 20

- 21 -

to 800 kGy, preferably 20 to 500 kGy, e.g. 20 to 200
kGy and particularly 40 to 120 kGy are in general
appropriate depending on the characteristics of the
polymer in question. For the purposes of promoting
cross-linking during irradiation, preferably from 0.2
to 15 weight per cent of a prorad such as a polyfunc-
tional vinyl or allyl compound, for example triallyl
cyanurate, triallyl isocyanurate (TAIC), methylene bis
acrylamide, metaphenylene diamine bis maleimide or
other crosslinking agents, for example as described in
U.S. patents Nos. 4,121,001 and 4,176,027, are incor-
porated into the composition prior to irradiaton.

The polymers used for the various layers may
include additional additives, for example reinforcing
or non-reinforcing fillers, stabilisers such as ultra-
violet stabilisers, antioxidants, acid acceptors and
anti-hydrolysis stabilisers, pigments, processing aids
such as plasticizers, halogenated or non-halogenated
flame retardants, hydrated metal oxides such as alumina
trihydrate and magnesium hydroxide, or decabromodi-
phenyl ether or combinations thereof, fungicides and
the like.

The wires and cables according to the invention
may be formed by conventional techniques. For example
the polymers may be blended together if necessary in a
mixer, together with any additional components, pelle-
tised, and then extruded onto a wire conductor. Other
non-preferred wires may be formed by a tape-wrapping
method. For example a polyamide, e.g. trimethylhexa-
methylene terephthalamide may be dissolved in a solu-
tion of a polyamic acid and, after the solvent has been

- 22 -

evaporated, the aromatic polymer may be imidized by
heat and cut into tapes which can then be wrapped
around the conductor and underlying layers. However,
it is preferred for the polymers to be melt-shapeable,
so that the wire insulation can be formed by extrusion.

The wires may be used individually as equipment or
"hook-up" wires, or airframe wires, or in bundles and
harnesses, both jacketted and unjacketted, and may be
used in multiconductor cables. The wires, harnesses or
cables may be unscreened or they may be provided with a
screen to protect them from electromagnetic inter-
ference, as well known in the art. In addition flat
cables may be formed using the insulation materials
according to the invention, either employing flat con-
ductors or round conductors.

The invention will now be described by way of
example with reference to the accompanying drawings in
which:

    Figure 1 is an isometric view of part of an
        electrical wire according to the invention;

    Figure 2 is a schematic view of the test arrange-
        ment for wet tracking; and

    Figure 3 is a schematic view of the test arrange-
        ment for dry arcing.

Referring initially to figure 1 of the accom-
panying drawings, an electrical wire comprises a con-
ductor 11 which may be solid or stranded as shown and

is optionally tinned. A 10 micrometre thick silica or
alumina layer 12 is formed on the conductor by a vacuum
deposition process, e.g. by sputtering, 5 micrometre
intermediate layer formed from for example aluminium
optionally being provided in order to improve adhesion
of the layer 12 to the conductor 11. A 100 to 200
micrometre thick aromatic polymer insulation 13 is then
extruded onto the coated conductor followed by a 100
micrometre thick tracking control layer 14 formed e.g.
from an ethylene-tetrafluoroethylene copolymer. After
both layers have been extruded, the insulation is irra-
diated by high energy electrons, to a dose of about 120
kGy to crosslink the tracking control layer 14 and
optionally also the aromatic polymer layer (depending
on the aromatic layer).

The following Examples illustrate the invention.
In the Examples the following test procedures were
used:

WET TRACKING TEST

This test is designed to simulate the condition
occuring when a damaged wire bundle comes into contact
with an electrolyte. Under actual conditions, the
electrolyte may be moisture containing dust particles
or other ionic contaminant. Damage to the bundle may
occur through a number of reasons e.g. abrasion, hydro-
lysis of the insulation, aging, etc. Current flow
through the electrolyte results in heating and evapora-
tion of the solution. This causes one or more dry
bands to appear across which the test voltage is

- 24 -

dropped, resulting in small, often intense, scintillations which damage the insulation.

Figure 2 shows the sample set-up. A wire bundle 1 is prepared from seven 14cm lengths 2 of 22AWG tinned-copper or nickel-plated copper conductor coated with a layer of the wire insulation under test. The bundle 1 is arranged with six wires around one central wire and is held together using tie wraps 3 so that the wires are not twisted. Two adjacent wires are notched circumferentially to expose 0.5mm bare conductor on each wire. The notches 4 are arranged such that they are 5mm apart with the tie wraps 5mm either side of them. One end of each wire is stripped to enable connections to be made to the power supply via insulated crocodile clips. The sample is held at an angle of 30 degrees to the horizontal using a simple clamp made of an electrically insulating resin so that the damaged wires are uppermost and the stripped ends are at the upper end of the bundle. A piece of filter paper 5 20 x 10mm wide is wrapped around the bundle approximately 2mm above the upper notch; this is best held in place with the upper tie wrap.

A peristaltic pump conveys the electrolyte from the reservoir to the sample via a dropping pipette 6, and a power supply is provided to energise the bundle. The electrolyte used is 2% sodium chloride and 0.02% sodium dodecyl sulphate surfactant in distilled or deionised water. The pump is set to deliver this solution at a rate of approximately 60mg per minute through the pipette 6 which is positioned 10mm vertically above the filter paper 5.

- 25 -

The power is supplied by a 3-phase 400Hz 115/200V generator of at least 5kVA capacity or a single phase 50Hz 115V transformer of at least 3kVA capacity. A device for recording time to failure is provided which records the time when either a wire goes open circuit, or when a circuit breaker comes out. Leakage currents can be followed with the use of current clamps surrounding the wires and connected to a suitable oscilloscope.

In the case of the three phase supply, adjacent wires of the bundle are connected to alternate phases of the power supply via 7.5A aircraft type circuit breakers with the central wire connected directly to neutral. In the case of the single phase supply, alternate wires are connected to neutral with the remaining wires including the central conductor to live. A few drops of electrolyte are allowed to fall onto the filter paper to ensure saturation prior to starting the test. The power is switched on and the timer started as soon as a leakage current has been detected. The test is allowed to continue until:

    a)   one or more circuit breakers come out;

    b)   a wire becomes open circuit; or

    c)   8 hours have elapsed.

The condition of the final bundle and the time to failure is noted in all cases. Where failure has occurred due to breakers coming out, the power is then reapplied and each breaker is reclosed in turn until there is no further activity. The condition of the bundle is again noted.

Where a wire has gone open circuit, the power is
reapplied and the test continued for a total of 8
hours. Wire insulations exhibiting "failures" due to
(b) or (c) may be considered to be good non wet-
tracking insulation if no more than two of the origi-
nally undamaged wires become open circuit.

Dry Arc Test

This test is designed to simulate what happens
when a fault in a wire bundle causes arcing under dry
conditions. A graphite rod is used to initiate the arc
which causes thermal degradation of the insulation.
Continuation of the fault current can only occur
through the wire bundle under test due to shorting
across adjacent phases through a conductive char, or
direct conductor-conductor contact such as might occur
if the insulation is totally removed by the duration of
the arc.

Figure 3 shows the sample set-up. A wire bundle
21 is prepared from seven 10cm lengths 22 of 22AWG
tinned-copper or nickel-plated copper conductor coated
with a layer of the wire insulation under test. The
bundle 22 is arranged with six wires around one central
wire and held together with tie wraps spaced about 5cm
apart. One of the outer wires is notched circumferen-
tially between the tie wraps to expose 0.5mm bare con-
ductor and one end of each wire is stripped to enable
connections to be made via insulating crocodile clips.

A rod 23 is provided which is made of a
spectrographically pure graphite, diameter 4.6mm, with

an impurity level not more than 20ppm. It is prepared before each test by sharpening one end using a conventional pencil sharpener of European design to give an angle of 10 degrees off vertical with a tip diameter of 0.4 ± 0.1mm. A 100g weight 24 is clamped onto the top of the rod 23 to maintain contact during the arc initiation and also acts as a device to limit the depth of penetration of the rod by restricting its downward travel. The rod passes through a PTFE bush which allows it to slide freely up and down.

The arrangement of levers enables precise positioning of the rod 23 on the wire bundle 21 which is held securely in place by means of a simple clamp 25 made of an electrically insulating resin and mounted on a block 26 made of the same material.

The power source can be either:

a) a 3-phase 400Hz 115/200V generator of at least 5kVA capacity

b) a single phase 50Hz 115V transformer, at least 3kVA capacity

c) 24V d.c. supplied by two 12V accumulators.

The fault current is detected by means of current clamps surrounding the connecting leads and the voltage at failure is measured using a 10:1 voltage probe. The transducer signals are fed into a multi-channel digital storage oscilloscope where they can be displayed and manipulated to obtain power curves (voltage x current) and energy (integration of power curve).

- 28 -

The wire bundle 21 is positioned in the clamp 25
so that the notched wire is uppermost. Adjacent wires
of the bundle are connected to different phases of the
supply through 7.5A aircraft type circuit breakers, and
the central wire is connected directly to neutral. In
the case of single phase or d.c. supplies, alternate
wires are connected to neutral or the negative ter-
minal, with the remaining wires, including the central
wire, connected through circuit breakers to live or the
postive terminal. The carbon rod is also connected to
neutral or the negative terminal and positioned so that
the point is in contact with the exposed conductor.
The gap between the 100g weight and the PTFE bush is
adjusted to the diameter of the insulated wire under
test, using a suitable spacer to limit the penetration
of the rod into the sample. A voltage probe is con-
nected across the damaged wire and the rod, and current
clamps positioned on each of the three phases, or on
the wires connected to the live side of the supply. A
protective screen is placed in front of the test set-up
and the power switched on. A material is deemed to
pass this test if:

    a)   no circuit breakers come out and the activity
          is relatively non-eventful, or
    b)   there is no further activity on resetting the
          breakers after a non-eventful test.

In addition, non-tracking materials will have
relatively few spikes in the current trace with a
correspondingly low total energy consumed. Tracking
materials, on the other hand, show many spikes usually
on all three phases, which are accompanied by violent
crepitation and large energy consumption.

CTI Test

This method is a modification of IEC 112 which
measures the low voltage track resistance (up to 600V)
as Comparative Tracking Index (CTI) of materials in the
presence of an aqueous contaminant.

The samples of each polymeric layer are prepared
by either compression or injection moulding plaques
with minimum thickness of 3mm and with sufficient area
to ensure that during the test no liquid flows over the
edge of the sample. Before testing, the surface of the
sample is cleaned with methanol to remove any surface
contamination.

The test apparatus is as described in IEC 112. It
consists of two platinum electrodes, each with one end
chisel-shaped to an angle of 30 degrees. The electro-
des are symmetrically arranged such that the opposing
chisel faces are vertical and 4.0±0.1mm apart when
placed on the surface of the specimen.

The power supply consists of a 0.5kVA transformer
capable of supplying an a.c. voltage in the range
100-600V at 50Hz. A rheostat is incorporated into the
circuit so that the short circuit current may be
adjusted to give 1.0±0.1 amp. An over-current relay is
provided which shuts off the HV supply when a current
of at least 0.5 amps flows for 2 seconds, the criteria
for failure.

A device for dropping electrolyte solution between
the electrodes is provided. This consists of a

peristaltic pump which draws liquid from a reservoir
and pumps it out of a needle situated at height of
30-40mm above and between the electrodes. The dropping
rate is set to 1 drop every 30±5 seconds with a drop
volume of 20±3 mm^3. Before the test, the needle is
cleaned and purged with several drops of electrolyte to
ensure the correct concentration of reagent is used.

The electrolyte solution used in these tests is
0.1±0.002% ammonium chloride and 0.01% sodium dodecyl
sulphate surfactant in deionised water and has a
resistivity of 405±5 ohm.cm at 23°C.

By using a surfactant, reproducible results have
been obtained on homogeneous samples. However, the
type of surfactant used can greatly affect the CTI
values obtained. Sodium dodecyl sulphate was chosen as
this gave a working range of below 150 (for known badly
tracking materials) to above 600 for non-tracking
materials.

Test Procedure

The specimen is put into position and the electro-
des lowered on to the surface. A suitable voltage is
chosen and the short circuit current adjusted accor-
dingly. The electrolyte is then allowed to drop bet-
ween the electrodes until either

    a)   tracking occurs
    b)   the sample erodes through to the supporting
         base
    c)   at 600V, the sample withstands 50 drops.

- 31 -

For those materials which track, the test is then repeated at at least three other voltages such that two voltages give results above 50 drops, and two give results below 50 drops. A curve of drops to failure versus applied voltage is plotted from which is read the voltage at which 50 drops would cause failure. This voltage is the comparative tracking index (CTI).

For those materials which withstand 50 drops at 600V, CTI is then quoted as >600 and the erosion of the sample is measured by preweighing a plaque of the material, running the test at 400V for 101 drops of electrolyte, and then reweighing the sample after removing any loose surface debris. The erosion is quoted as mg of material lost.

For those samples which penetrate through to the supporting base during the test, erosion is quoted as mg lost at 400V after 101 drops, or after complete penetration, stating the number of drops required for this to occur e.g. 75mg (80 drops).

The following wire constructions were prepared by use of a 20mm Baughan extruder for the polymeric layers and by sputtering for the inorganic layers. In the cases where a blend has been used, it has been prepared using a Baker Perkins twin screw extruder. The conductor was 22 AWG nickel plated copper unless otherwise stated. The results for the wet and dry tracking tests are shown in the table.

Example 1

A 10 μm silica arc control layer on top of a 5 μm aluminium interlayer was coated with 160 μm of polyaryletheretherketone as the primary insulation layer and 75 μm crosslinked ethylenetetrafluoroethylene as the secondary tracking control layer.

Example 2

A 6-7 μm alumina arc control layer on top of a 7 um aluminium interlayer was coated with 125 μm of polyaryletheretherketone as the primary insulation layer and 125 μm of a blend of polytetramethylene terephthalate and a poly(ether-ester) block copolymer comprising approximately 57% by weight polybutylene terephthalate hard blocks and approximately 43% by weight poly(butylene glycol polyether terephthalate) soft blocks in the ratio of 70:30 as the secondary tracking control layer. (22 AWG copper conductor).

Example 3

A 6 μm silica arc control layer on top of a 5.7 μm aluminium interlayer was coated with 125 μm of polyaryletheretherketone as the primary insulation layer and 125 μm of a blend of polytetramethylene terephthalate and a poly(ether-ester) block copolymer comprising approximately 57% by weight polybutylene terephthalate hard blocks and approximately 43% by weight poly(butylene glycol polyether terephthalate) soft blocks in the ratio of 70:30 as the secondary tracking control layer.

- 33 -

Example 4 (Control)

A 6-7 μm silica arc control layer on top of a 7 μm aluminium interlayer was coated with 125 um of poly-aryletheretherketone as an insulating layer.

Example 5 (Control)

100 μm polyaryletheretherketone as the inner insu-lating layer with 100 μm of a blend of polytetramethylene terephthalate and a poly(ether-ester)block copolymer comprising approxima-tely 57% by weight poly(tetramethylene terephthalate) hard blocks and approximately 43% by weight poly(tetramethylene glycol polyether terephthalate) soft blocks in the ratio of 70:30 as the outer insu-lating layer.

Example 6 (Control)

A 125 μm polyaryletheretherketone layer as the sole insulation.

- 34 -

TABLE

Tracking Test Results

Example	Arc Control Layer	Primary Insulation	Secondary Tracking Control Layer	(50Hz,115V)	
				Wet	Dry
1	Silica	PEEK	Cross-linked ETFE	Pass	Pass
2	Alumina	PEEK	PBT/poly(ether-ester) block co-polymer	Pass	Pass
3	Silica	PEEK	PBT/poly(ether-ester) block co-polymer	Pass	Pass
4 (Control)	Silica	PEEK		Fail	Fail
5 (Control)	-	PEEK	PBT/poly(ether-ester)block co-polymer	-	Fail
6 (Control)	-	PEEK	-	Fail	Fail

The CTI of each of the secondary tracking control
layers of Examples 1 to 3 and 5 was greater than 600 V.

- 35 -

CLAIMS:

1.   An electrical wire which comprises an elongate
electrical conductor, an inorganic arc-control layer
surrounding the conductor, an insulating layer which
surrounds the arc-control layer and comprises an aroma-
tic polymer, and a secondary tracking control layer
surrounding the insulating layer, the secondary
tracking control layer having a comparative tracking
index of at least 300V.

2.   A wire as claimed in claim 1, wherein the arc-
control layer has a char residue of not more than 2% by
weight.

3.   A wire as claimed in claim 2, wherein the arc-
control layer has a char residue of not more than 0% by
weight.

4.   A wire as claimed in any one of claims 1 to 3,
wherein the arc-control layer has a thickness in the
range of from 0.1 to 10 micrometres.

5.   A wire as claimed in claim 4, wherein the
inorganic material has been deposited by a vacuum depo-
sition process.

6.   A wire as claimed in claim 4 or claim 5, wherein
the inorganic material comprises an oxide, nitride or
oxynitride of aluminium, silicon, or titanium.

7.   A wire as claimed in any one of claims 1 to 6,
wherein the aromatic polymer comprises a polyaryl ether

ketone, a polyaryl ether sulphone, a polyarylether, a polyarylate and/or a polyether imide.
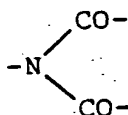
8.   A wire as claimed in claim 7, wherein the aromatic polymer comprises:

i)   units of the general formula:
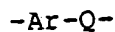
$$-Ar-Q-$$

the units being the same or different,

wherein Ar represents an unsubstituted or substituted divalent aromatic radical and Q represents $-O-$, $-S-$, $-SO_2-$, $-CO-$, $-NH-CO-$ or $-COO-$, or Ar represents a polyvalent radical and Q represents

$$-N\overset{\displaystyle CO-}{\underset{\displaystyle CO-}{\Big\langle}}$$

the Q radical preferably being bonded directly to an aromatic carbon atoms;

ii) a   crystalline   polyarylene   ether   comprising recurring units of the formula:

$$-O-E-O-E'-$$
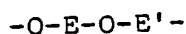
wherein E is the residue of a dihydric phenol and E' is the residue of an aromatic compound having an electron withdrawing group in at least one of the positions ortho and para to the valence bonds, the E and E' radi-

cals being linked to the -O- radicals through aromatic carbon atoms; or

iii) polyether imide or polysulphone imide which comprises recurring units of the formula
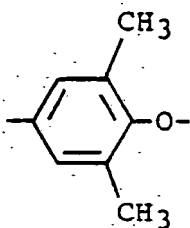
$$-Q-Z \overset{\displaystyle \overset{O}{\underset{\displaystyle \parallel}{C}}}{\underset{\displaystyle \underset{\displaystyle \parallel}{C}}{}} N-R'-N \overset{\displaystyle \overset{O}{\underset{\displaystyle \parallel}{C}}}{\underset{\displaystyle \underset{\displaystyle \parallel}{C}}{}} Z-Q-R-$$
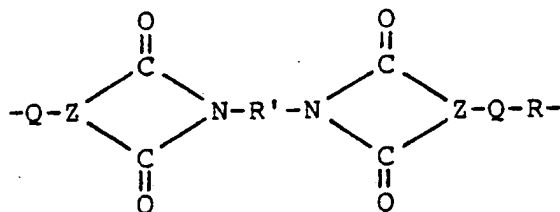
where Q is -O- or $-SO_2$, z is a trivalent aromatic radical, R is a divalent aromatic radical and R' is a divalent organic radical.
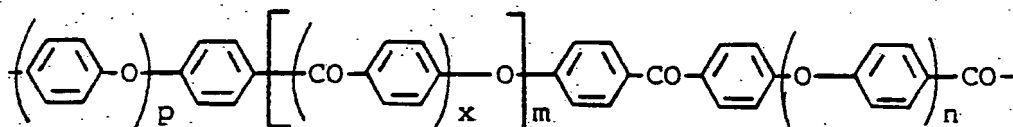
9.　　　　A wire as claimed in claim 8, wherein the aromatic polymer comprises a polymer having a repeating unit of the formula:

(1)　—⟨aromatic⟩—⟨aromatic⟩—O—⟨aromatic⟩—CO—

(2)　—⟨aromatic⟩—O—⟨aromatic⟩—O—⟨aromatic⟩—CO—
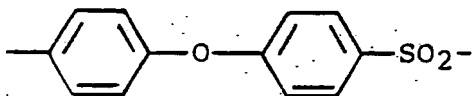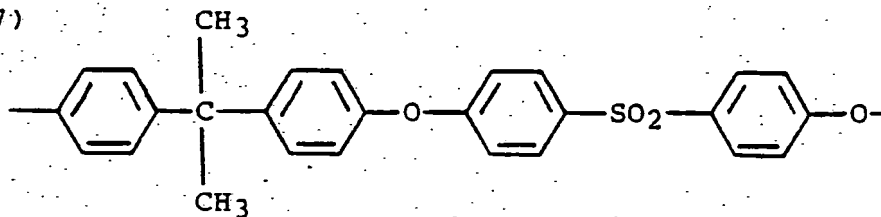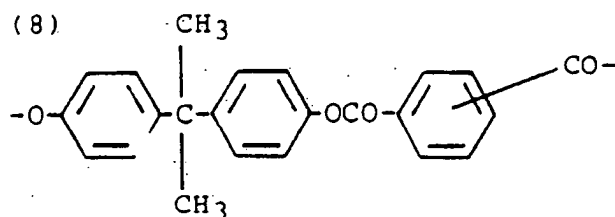
(3)　—⟨aromatic⟩—O—⟨aromatic⟩—CO—
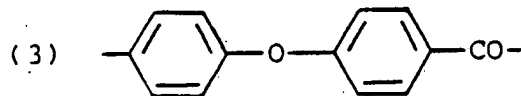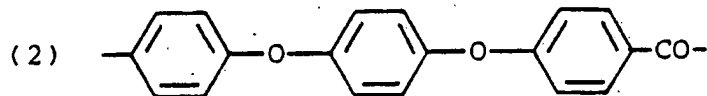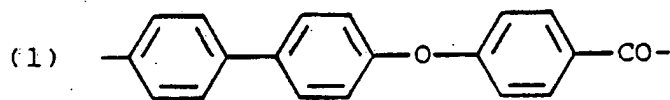
(4)

(5)

wherein each of x, m and n is 0 or 1, with n being 0
when x is 1, p is an integer from 1 to 4, with m being
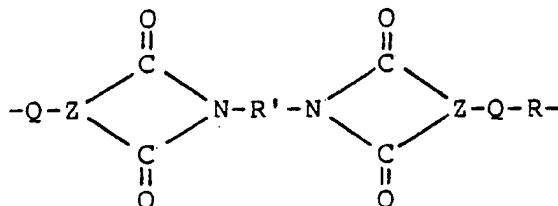1 and x being 0 when p is greater than 1,

(6)

(7)

(8)

in which the units may be derived wholly from
terephthalate acid or isophthalic acid or both;

(9)

10.   A wire as claimed in any one of claims 1 to 9,
wherein the aromatic polymer is blended with one or
more aliphatic polymers.

11.   A wire as claimed in any one of claims 1 to 10,
wherein the insulating layer is in the form of a plura-
lity of layers, at least the outermost layer comprising
the aromatic polymer, and at least the inner layer
comprising a polymer having a carbonaceous char residue
of not more than 10% by weight.

12.   A wire as claimed in claim 11, wherein the inner
layer of the insulating layer comprises an aliphatic
polymer.

13.   A wire as claimed in any one of claims 10 to 12,
wherein the or each aliphatic polymer of the insulating

layer comprises a polyolefin; a copolymer of an olefin
with an olefin, an alkyl acetate, an alkyl acrylate, a
vinyl ester; a polyamide; a polyether; a polyester, an
ionomer or an acrylic polymer.

14.   A wire as claimed in any one of claims 1 to 13,
wherein the secondary tracking control layer has a com-
parative tracking index of at least 400 preferably 500.

15.   A wire as claimed in any one of claims 1 to 14,
wherein the secondary tracking control layer has a char
residue of not more than 5%.

16.   A wire as claimed in any one of claims 1 to 15,
wherein the secondary tracking control layer comprises
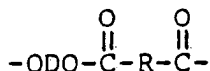an aliphatic polymer.

17.   A wire as claimed in claim 16, wherein the
aliphatic polymer of the secondary tracking control
layer is a polyolefin, a copolymer of an olefin with an
olefin, an alkyl acetate, an alkyl acrylate or a vinyl
ester, a polyamide, a polyester, an ionomer or an acry-
lic rubber.

18.   A wire as claimed in claim 17, wherein the
aliphatic polymer of the secondary tracking control
layer comprises polyethylene, a crystalline polyamide,
an amorphous aromatic/aliphatic polyamide, an ionomer
based on a metal salt of methacrylated polyethylene,
polybutylene terephthalate, a styrene/diene di- or tri-
block copolymer or hydrogenated version thereof or a
block copolymer having long-chain ester units of the
general formula:
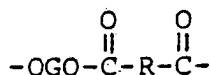
$$-OGO-\overset{\overset{\displaystyle O}{\|}}{C}-R-\overset{\overset{\displaystyle O}{\|}}{C}-$$

and short-chain ester units of the formula

$$-ODO-\overset{\overset{\displaystyle O}{\|}}{C}-R-\overset{\overset{\displaystyle O}{\|}}{C}-$$

in which G is a divalent radical remaining after
the removal of terminal hydroxyl groups from a
polyalkylene oxide) glycol, preferably a poly (C_2
to C_4 alkylene oxide) having a molecular weight of
about 600 to 6000; R is a divalent radical
remaining after removal of carboxyl groups from at
least one dicarboxylic acid having a molecular
weight of less than about 300; and D is a divalent
radical remaining after removal of hydroxyl groups
from at least one diol having a molecular weight
less than 250.

19.   A wire as claimed in claim 16, wherein the
aliphatic polymer of the secondary tracking control
layer is a fluorinated polymer.

20.   A wire as claimed in claim 19, wherein the
aliphatic polymer of the secondary tracking control
layer is a homopolymer or copolymer of vinylidine
fluoride polymer, a hexafluoropropylene, poly-
tetrafluoroethylene or a C_1-C_5 perfluoroalkoxy sub-
stituted perfluoroethylene.

21.   A wire as claimed in any one of claims 1 to 19,
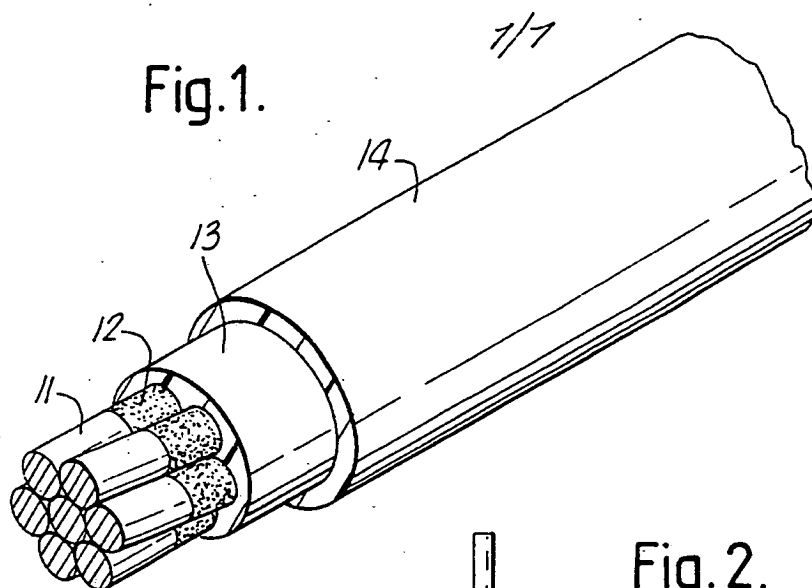wherein the secondary tracking control layer is cross-
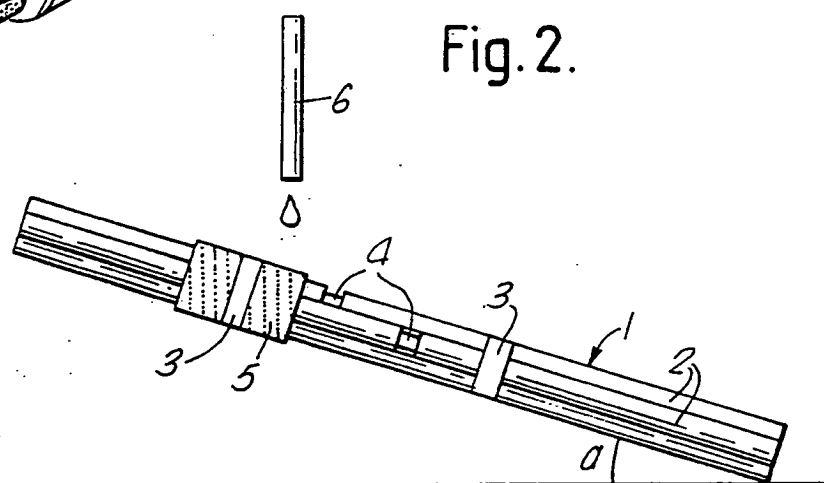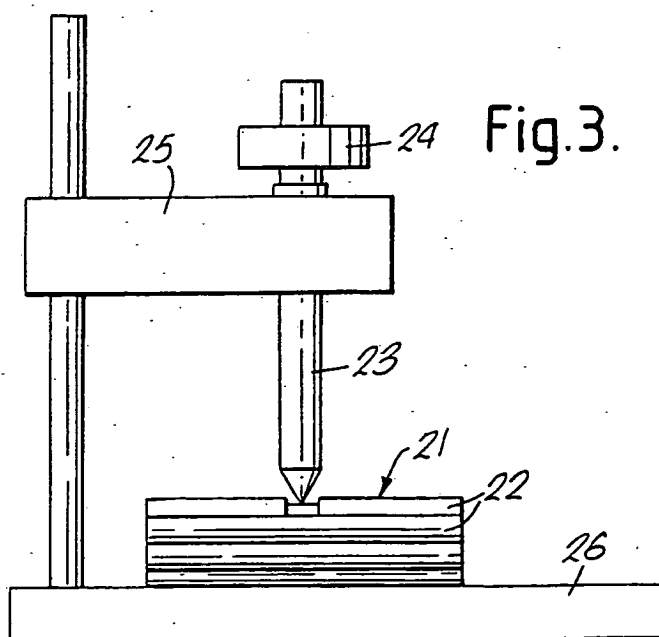linked.

Fig.1.   1/7

14
13
12
11

Fig.2.

6

4
3   3
5
3
1
2
a

Fig.3.

25
24
23
21
22
26

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply indicate all) *

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC⁴: H 01 B 7/02; H 01 B 3/10; H 01 B 3/42; H 01 B 3/44

II. FIELDS SEARCHED

Minimum Documentation Searched ⁷

Classification System	Classification Symbols
IPC⁴	H 01 B

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched ⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT *

Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	EP, A, 0188370 (RAYCHEM LTD) 23 July 1986, see claims 1,3,5,6,13,15; page 10, lines 4-27; page 11, paragraph 2	1,4,6,7,11-13,16-21
Y		1,4,6-9,11-13,16-21
	--	
X	EP, A, 0132343 (RAYCHEM LTD) 30 January 1985, see claims 1,10,14,15,16,19; page 13, line 33 - page 15, line 12; page 38, lines 15-21	1,4-13,16-21
	& GB, A, 2144260 (RAYCHEM LTD) 27 February 1985 (cited in the application)	
	--	
A	EP, A, 0157466 (IMPERIAL CHEMICAL IND. PLC) 9 October 1985 see claims 1,7; page 2, line 35 - page 3, line 19	1,7,8,9
	--	
Y	EP, A, 0103487 (RAYCHEM CORP.) 21 March 1984, see claims 1-3,5-9	1,4,6-9, 11-13,16-21

---

* Special categories of cited documents: ¹⁰

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
4th October 1988	31 10 83

International Searching Authority	Signature of Authorized Officer
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.

GB 8800546
SA   23149

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 19/10/88
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A- 0188370	23-07-86	JP-A-	61165910	26-07-86
EP-A- 0132343	30-01-85	WO-A-	8500462	31-01-85
		GB-A,B	2144260	27-02-85
		AU-A-	3151584	07-02-85
		GB-A,B	2182800	20-05-87
		GB-A,B	2183079	28-05-87
		GB-A,B	2183080	28-05-87
		EP-A-	0249252	16-12-87
		CA-A-	1236537	10-05-88
EP-A- 0157466	09-10-85	JP-A-	60238357	27-11-85
		US-A-	4654263	31-03-87
EP-A- 0103487	21-03-84	GB-A,B	2127210	04-04-84
		JP-A-	59073807	26-04-84
		US-A-	4521485	04-06-85
		CA-A-	1214528	25-11-86
		US-A-	4678709	07-07-87

EPO FORM P0479